This is an update of the article *Aversion to In-vehicle Crowding before, during and after the COVID-19 pandemic* published in Transportation Findings in August 2022. The original paper presents results from four data collections. This update adds results from a fifth data collection from autumn 2022 (see new Figure 4).

# Aversion to In-vehicle Crowding before, during and after the COVID-19 pandemic – an update with post-COVID data from autumn 2022

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Abstract:

Based on five consecutive stated choice surveys, we estimate changes in public transport user's valuation (marginal costs) of in-vehicle crowding due to the COVID-19 pandemic in two Norwegian cities. Compared to the pre-COVID level (November 2018), we find significantly higher costs during COVID (November 2021). Post-COVID costs from May 2022 are significantly reduced but remain above the pre-COVID level. Post-COVID results from November 2022 show a further reduction in costs to a level that is no longer significantly different from the pre-COVID levels

Keywords: in-vehicle crowding, COVID-19, stated preference, public transport

1. Questions

There is a hypothesis that preference for crowding in public transport vehicles (in-vehicle crowding) changed during the COVID-19 pandemic due to an increased risk of getting a viral infection and increased discomfort of sitting or standing close to other persons. For transport planning, a relevant question is if the valuation/marginal costs of crowding in the post-COVID period differs from the pre-COVID period. If costs persist at a higher level, this might indicate long-term changes in preferences that transport planners should account for when designing future public transport supply.

Our research question is therefore: To what degree has public transport user's aversion to crowding – measured by crowding multipliers on the value of travel time saving (Wardman and Whelan 2011) – changed during and after the COVID-19 pandemic compared to pre-COVID level?

Our empirical evidence are from two Norwegian cities, and adds to a growing literature on COVID-related crowding costs (Cho and Park (2021), Aghabayk, Esmailpour and Shiwakoti (2021), Basnak, Giesen and Muñoz (2022), Shelat, Cats and van Cranenburgh (2022)). To our knowledge, this is the first paper that presents comparable results from all three periods, i.e. before, during and after the pandemic.

2. Methods

We estimate crowding multipliers on the value of travel time savings based on binary stated choice data, using mixed logit models. Available information that enters our statistical model is dummy variables for the round of data collection $D_a$ with a ={1,2,3,4,5}, travel time $T_i$ in minutes for alternative i ={1,2}, and dummy variables indicating the crowding situation $C_{i,s,k}$ where s={sitting, standing} indicates if one sits or stands over the whole trip and $k = \{ \begin{matrix} 1, \ldots, 10 \; for \; s = sitting \\ 5, \ldots, 10 \; for \; s = standing \end{matrix} \}$ indicates the crowding level as illustrated Figure 1.

*Figure 1: Illustration of crowding levels (here in the case of train and metro)*

Figure 2 shows an example of a choice task. The three attributes travel time, sitting place and crowding level were established based on reported reference values and combined by means of an orthogonal design (Flügel et al. 2020). A variant of the choice experiment, assigned to 50% of the sample, omitted the verbal description of sitting place and instead showed seat position in the illustration of the crowding level.

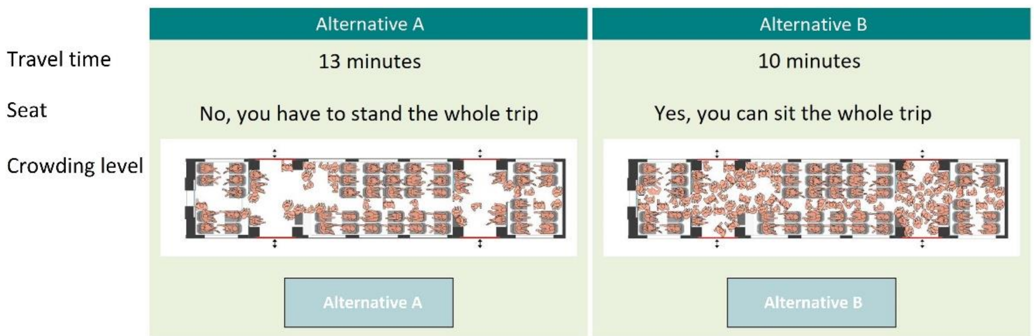


*Figure 2: Example of a task in the choice experiment (translated from Norwegian)*

In our model, the utility function of alternative *i* for respondent *n* in choice task *t* is given as

$$U_{n,t,i,a} = \mu_a * (\alpha_i + \sum_a \sum_s \sum_k (\beta_{a,s,k} * D_a * C_{n,t,i,s,k} * T_{n,t,i,a,s,k})) + \varepsilon_{n,t}$$

with

- $\varepsilon_{n,t}$ being i.i.d. Gumbel distributed error terms
- $\mu_a$ being scale parameters for the different data collections *a*. For normalization, we apply $\mu_1 \equiv 1$
- $\alpha_i$ being constant terms. For normalization, we apply $\alpha_1 \equiv 0$[1]
- $\beta_{a,s,k}$ being parameters capturing the marginal utility of travel time in different crowding situations. The marginal utility of travel in uncrowded situations, i.e. $\beta_{a,sitting,1}$, is assumed normally distributed over respondents *n* to account for unobserved taste heterogeneity. For normalization, we set the mean values of $\beta_{a,sitting,1}$ to minus 1.

With the applied normalization, the absolute values of $\beta_{a,s,k}$ represent the crowding multipliers in different situations (defined by *s* and *k*) given the round of data collection *a*.

Our data collection was done in five rounds (R1 – R5) using different recruitment techniques. Recruitment was concentrated in the area of the Norwegian capital Oslo (the largest urban area in Norway) and Trondheim (the fourth largest urban area in Norway). Table 1 gives an overview over the samples. Note that all respondents in round 4 and 5 also participated in round 2 and/or round 3 (mainly round 3).

[1] The estimated value of $\alpha_2$ captures possible effects of alternatives being presented on the right side of the screen.

*Table 1: Comparison of samples*

| **Comparison of samples** | **R1** | **R2** | **R3** | **R4** | **R5** |
|---|---|---|---|---|---|
| Period | Nov. 2018 | April 2021 | Nov. 2021 | May 2022 | Nov 2022 |
| Main recruitment | Intercept method on board and at stations using tablets, with the option to answer later on own device | Commercial E-mail register from a postal service, invitations by email | Mobile register from commercial provider, SMS invitations | Recruited from respondents that left their contact info (mobile number or email address) in R3 (and R2). | Same as R4 |
| Nr. of completed questionnaires | 680 | 475 | 9701 | 2912 | 2588 |
| Female share | 54.4% | 55.2% | 51.0% | 51.7% | 51.2% |
| Age distribution<br>(under 30, 30-60, over 60 years) | 35.6%, 54.6%, 9.4% | 21.1%, 66.5%, 12.4% | 6.8%, 54.1%, 39.1% | 2.6%, 49.7%, 47.7% | 2.8%, 50.2%, 47.1% |
| Mode shares (train, metro, tram, bus) | 22.8%, 25.0%, 19.6%, 32.6% | 21.9%, 25.5%, 10.7%, 41.9% | 23.8%, 29.0%, 9.6%, 37.5% | 22.3%, 29.1%, 10.2%, 38.4% | 21.7%, 26.7%, 10.5%, 41.2% |
| Share using mask in PT | N.A. | 96.6% | 33.9% | 19.1% | 12.6% |
| Share agreeing that they are worried about infection in PT | N.A. | 33.7% | 33.6% | 17.2% | 15.0% |
| Share being vaccinated | N.A. | 25.5% | 98.3% | 98.6% | 99.0% |
| Context of the COVID pandemic in Norway | Pre-COVID | Mild lock-down in Oslo; several national measures; initial vaccination campaign | No lockdown but some local measures reintroduced after increases in infection and rumors of omicron variant | Post-COVID: all measures were removed already in February 2022 | Same as R4 |

### 3. Findings

The last four lines of Table 1 paint a picture of the COVID situation in Norway at the different points in time. Based on this context, we expected crowding multipliers to be greater during the pandemic (April 2021 and November 2021) compared to 2018 values, and 2022 values to be close to 2018 values.

This was largely confirmed as shown in Figure 3[2]. Looking at the two left-most panels we see that estimated crowding multipliers were significantly higher during the pandemic (November 2021) compared to pre-COVID (November 2018). Our assessment about significance is based on the robust standard errors (and T-values) of the estimated beta-parameters. They are shown in the form of 95% confidence intervals in the Figure 3. The figure also shows that the post-COVID (May 2022) values are significantly lower compared to November 2021. The post-COVID values (May 2022) remain somewhat above the pre-COVID levels, however, here the confidence intervals are largely overlapping.

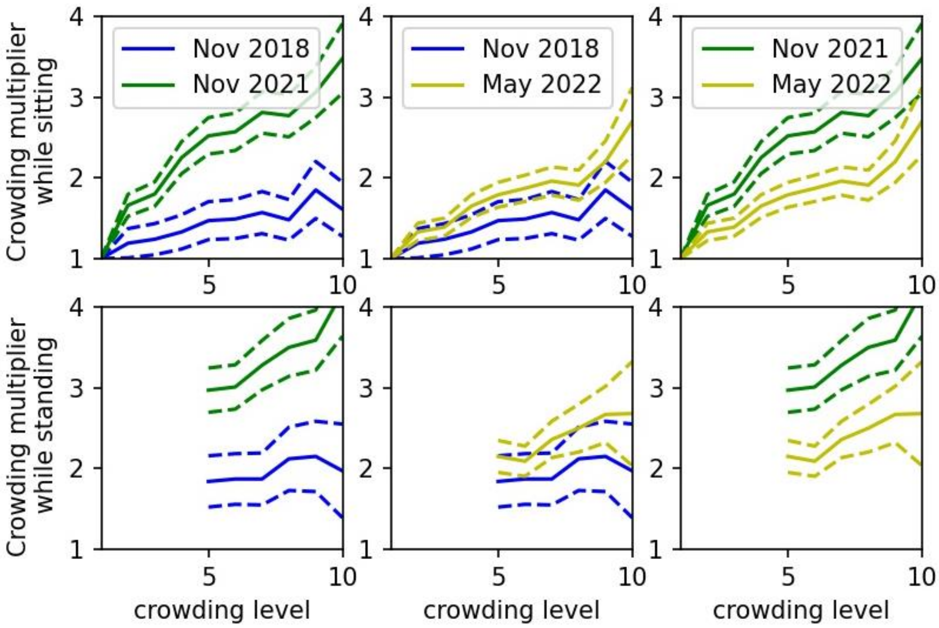


*Figure 3: Estimated crowding multipliers while sitting (upper panel) and standing (lower panel); comparison of selected pairs of data collections. 95% confidence intervals given in dashed lines. November 2018, November 2021 and May 2022 compared to each other.*

[2] Note that the April 2021 results are somewhat indecisive (likely due to the low number of observations) and therefore not shown here.

The results for the post covid results in November 2022 are shown in Figure 4. *Compared to November 2021 and April 2022, the crowding multipliers in November 2022 are further reduced. They stay somewhat above the pre-COVID (November 2018 level), however, the differences are no longer statistically significant.*

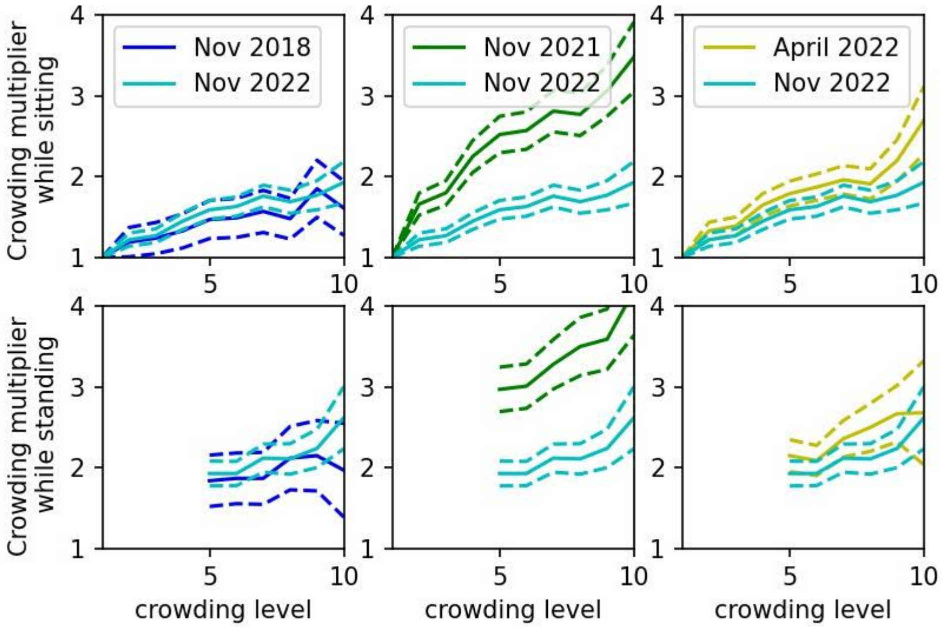


*Figure 4: Estimated crowding multipliers while sitting (upper panel) and standing (lower panel); comparison of selected pairs of data collections. 95% confidence intervals given in dashed lines. November 2022 compared to data collections in Figure 3.*

The absolute values of the pre-COVID crowding multipliers seem to compare well against other studies (Wardman and Whelan (2011), Kroes et al. (2014), Hörcher, Graham and Anderson (2017), Tirachini et al. (2017)). While our COVID-related values are rather high, some high values (of up to 5.1) are also found in Basnak et al. (2022).

For context, Table 2 gives the share of respondents agreeing to the statement that they may feel discomfort when standing close to other persons.

*Table 3: Share of respondents agreeing that they may feel discomfort standing close to other persons*

| Subsample | Round 1 | Round 2 | | Round 3 | | Round 4 | | Round 5 | |
|---|---|---|---|---|---|---|---|---|---|
| | November 2018 | "before COVID" | "today" (April 2021) | "before COVID" | "today" (Nov. 2021) | "before COVID" | "today" (May 2022) | "before COVID" | "today" (Nov 2022) |
| **All** | 57.8 % | 61.3 % | 91.2 % | 58.3% | 87.4 % | 56.5% | 71.7 % | 57.4% | 69.0% |
| **Male** | 49.4 % | 55.5 % | 85.6 % | 54.3 % | 82.3 % | 51.8 % | 65.6 % | 51.6% | 62.1% |
| **Female** | 64.9 % | 65.6 % | 95.4 % | 62.0 % | 92.2 % | 60.2 % | 77.0 % | 62.2% | 74.4% |
| **Under 30 years** | 56.2 % | 70.0 % | 93.0 % | 63.5 % | 85.0 % | 56.6 % | 69.7 % | 66.7% | 73.6% |
| **30-60 years** | 60.2 % | 59.2 % | 91.1 % | 58.2 % | 87.1 % | 59.4 % | 72.8 % | 60.4% | 70.0% |
| **Over 60 years** | 50.0 % | 57.6 % | 88.1 % | 57.6 % | 88.2 % | 53.4 % | 70.8 % | 53.7% | 67.6% |

We see that the shares increased substantially from round 1 (pre-COVID) to round 2 (April 2021), but has since been on a decline. Still, the 69.0% in round 5 (post-COVID) is substantially above the pre-COVID share, both compared to the 2018-sample and compared to retrospective questions within the 2022-samples ("before COVID"). This indicates that there might be long-term shifts in preferences.

Some caveats should be taken regarding the different samples, e.g. in respect to the age distributions. However, note that the shares in Table 2 for the 2018 sample is rather consistent with the "before COVID" shares from the later samples. This is encouraging with respect to concerns regarding representativity and comparability of the samples. It also seems like the perception of discomfort is less related to age compared to gender.

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## References

Aghabayk, K., J. Esmailpour & N. Shiwakoti (2021) Effects of COVID-19 on rail passengers' crowding perceptions. *Transportation Research Part A: Policy and Practice,* 154**,** 186-202.

Basnak, P., R. Giesen & J. C. Muñoz (2022) Estimation of crowding factors for public transport during the COVID-19 pandemic in Santiago, Chile. *Transportation Research Part A: Policy and Practice,* 159**,** 140-156.

Cho, S.-H. & H.-C. Park (2021) Exploring the Behaviour Change of Crowding Impedance on Public Transit due to COVID-19 Pandemic: Before and After Comparison. *Transportation Letters,* 13**,** 367-374.

Flügel, S., A. H. Halse, N. Hulleberg, G. N. Jordbakke, K. Veisten, H. B. Sundfør & M. Kouwenhoven. 2020. Verdsetting av reisetid og tidsavhengige faktorer. Dokumentasjonsrapport til Verdsettingsstudien 2018-2019.

Hörcher, D., D. J. Graham & R. J. Anderson (2017) Crowding cost estimation with large scale smart card and vehicle location data. *Transportation Research Part B: Methodological,* 95**,** 105-125.

Kroes, E., M. Kouwenhoven, L. Debrincat & N. Pauget (2014) Value of Crowding on Public Transport in île-de-France, France. *Transportation Research Record,* 2417**,** 37-45.

Shelat, S., O. Cats & S. van Cranenburgh (2022) Traveller behaviour in public transport in the early stages of the COVID-19 pandemic in the Netherlands. *Transportation Research Part A: Policy and Practice,* 159**,** 357-371.

Tirachini, A., R. Hurtubia, T. Dekker & R. A. Daziano (2017) Estimation of crowding discomfort in public transport: Results from Santiago de Chile. *Transportation Research Part A: Policy and Practice,* 103**,** 311-326.

Wardman, M. & G. Whelan (2011) Twenty Years of Rail Crowding Valuation Studies: Evidence and Lessons from British Experience. *Transport Reviews,* 31**,** 379-398.